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Die beiliegenden Akten stimmen überein mit den ursprünglichen Unterlagen der auf den nächsten Seiten bezeichneten, beim unterzeichneten Amt als Anmeldeamt im Sinne von Art. 10 des Vertrages über die internationale Zusammenarbeit auf dem Gebiet des Patentwesens (PCT) eingegangenen Patentanmeldung.

Attestation

Les documents ci-joints sont conformes aux pièces originales relative à la demande de brevet spécifiée aux pages suivantes, déposées auprès de l'Office soussigné, en tant qu'Office récepteur au sens de l'article 10 du Traité de coopération en matière de brevets (PCT).

Confirmation

It is hereby confirmed that the attached documents are corresponding with the original pages of the international application, as identified on the following pages, filed under Article 10 of the Patent Cooperation Treaty (PCT) at the receiving office named below.

DOCUMENT DE PRIORITÉ

PRÉSENTÉ OU TRANSMIS CONFORMÉMENT À LA RÈGLE 17.1.a) OU b)

Berne, 29 mars 2005

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Administration Patente
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Patent Administration

Rolf Hofstetter

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13-26.B.WO-P

PCT REQUEST

Original (for SUBMISSION)

0	**For receiving Office use only**	
0-1	International Application No.	PCT/CH 2004/000197
0-2	International Filing Date	30. März 2004 (30.03.2004)
0-3	Name of receiving Office and "PCT International Application"	RO/CH - Demande international PCT
0-4	**Form - PCT/RO/101 PCT Request**	
0-4-1	Prepared Using	PCT-SAFE [EASY mode] Version 3.50 (Build 0002.150)
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	Swiss Federal Intellectual Property Institute (RO/CH)
0-7	**Applicant's or agent's file reference**	13-26.B.WO-P
I	**Title of Invention**	A SILICON LIGHT PHASE MODULATOR BASED ON THE GATE-ALL-AROUND MOFSET TECHNOLOGY
II	**Applicant**	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States except US
II-4	Name:	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE (EPFL)
II-5	Address:	CM-Ecublens 1015 Lausanne Switzerland
II-6	State of nationality	CH
II-7	State of residence	CH
II-8	Telephone No.	+41-21.693.35.82
II-9	Facsimile No.	+41-21.693.70.40
III-1	**Applicant and/or inventor**	
III-1-1	This person is:	applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	MOSELUND, Kirsten
III-1-5	Address:	av. de la Dôle 9 1005 Lausanne Switzerland
III-1-6	State of nationality	DK
III-1-7	State of residence	CH

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13-26.B.WO-P

PCT REQUEST

Original (for SUBMISSION)

III-2	**Applicant and/or inventor**	
III-2-1	This person is:	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	DAINESI, Paolo
III-2-5	Address:	ch. de la Lisière 6 1018 Lausanne Switzerland
III-2-6	State of nationality	IT
III-2-7	State of residence	CH
III-3	**Applicant and/or inventor**	
III-3-1	This person is:	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	IONESCU, Mihai, Adrian
III-3-5	Address:	Av. Victor-Ruffy 16bis 1014 Lausanne Switzerland
III-3-6	State of nationality	RO
III-3-7	State of residence	CH
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/ has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name (LAST, First)	ROLAND, André
IV-1-2	Address:	Avenue Tissot 15 1001 Lausanne Switzerland
IV-1-3	Telephone No.	+41.21.321.44.10
IV-1-4	Facsimile No.	+41.21.321.44.12
IV-1-5	e-mail	contact@andreroland.com
V	**DESIGNATIONS**	
V-1	**The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.**	
VI-1	**Priority Claim**	NONE
VII-1	**International Searching Authority Chosen**	European Patent Office (EPO) (ISA/EP)

13-26.B.WO-P

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VIII	**Declarations**	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	-	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-	
IX	**Check list**	number of sheets	electronic file(s) attached
IX-1	Request (including declaration sheets)	4	-
IX-2	Description	3	-
IX-3	Claims	1	-
IX-4	Abstract	1	✓
IX-5	Drawings	0	-
IX-7	TOTAL	9	
	Accompanying Items	paper document(s) attached	electronic file(s) attached
IX-8	Fee calculation sheet	✓	-
IX-17	PCT-SAFE physical media	-	✓
IX-19	**Figure of the drawings which should accompany the abstract**		
IX-20	**Language of filing of the international application**	English	
X-1	**Signature of applicant, agent or common representative**		
X-1-1	Name:	ROLAND, André	
X-1-2	Name of signatory		
X-1-3	Capacity		

13-26.B.WO-P

PCT REQUEST

Original (for **SUBMISSION**)

FOR RECEIVING OFFICE USE ONLY

10-1	Date of actual receipt of the purported international application	30. März 2004 (30.03.2004)
10-2	Drawings:	
10-2-1	Received	
10-2-2	~~Not received~~	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/EP
10-6	Transmittal of search copy delayed until search fee is paid	X

FOR INTERNATIONAL BUREAU USE ONLY

11-1	Date of receipt of the record copy by the International Bureau	

A Silicon light phase modulator based on the gate-all-around MOSFET technology

Double gate (DG) and gate-all-around (GAA) MOS electronic devices have been proposed, analyzed and validated in the last few years in order to develop new device structures that can keep pace with the SIA roadmap [1 - 4].

The concept of those devices is to have a thin Silicon film between two gate oxide parallel layers (for the case of the DG), or to have a thin Si film completely wrapped by the gate oxide (for the case of the GAA). For thick silicon films this would be nothing more than having two or four MOS transistors in parallel in a fancy compact integration configuration, but for thin Si films quantum effects becomes relevant, changing dramatically the device performances. In the subthreshold region, in fact, the film is completely depleted, and at the threshold voltage the whole film, if sufficiently thin, becomes inverted (volume inversion region) and, in this case, the inverted carriers need to be considered as a quantum two dimensional electron gas. The result is that the whole film volume becomes the conducting channel thus avoiding the typical MOS stray effects due to the surface channel. The advantages are: higher mobility and transconductance, near ideal subthreshold slope, low subthreshold capacitance, and good scalability, just to cite the most important ones.

Though the first reported results of GAA MOS devices have been shown in Silicon on insulator (SOI) substrates, a new substrate, called Silicon on nothing (SON), looks very promising and a first demonstration has been published in 2002 [5]. SON substrates have been initially developed with the purpose of enhancing the characteristics of fully depleted SOI MOS devices in a new cheaper substrate [6, 7]. The basic concept is to have a Silicon Germanium sacrificial layer between the bulk and the thin, device, Silicon layer. The SiGe layer can be then selectively etched during the fabrication process, just above the transistor channel, to isolate it from the bulk beneath; the source and drain regions remain, on the contrary, contacted with the bulk Silicon. The resulting MOS transistor has all the advantages of thin film channels isolated from the bulk (low stray capacitance, fully depletion), like in SOI substrates, together with a new heat evacuation method through the substrate via source and drain, solving one of the major drawbacks of SOI. Other relevant advantages have been reported in the literature [6, 7].

We have conceived a new device for light phase modulation in Silicon based on the GAA structure. This device can be fabricated in a SON substrate using the same process developed for electronic devices.

Light phase modulation in Silicon can be performed by thermal heating, or by variation of free charges. The first one is a slow phenomenon and cannot be useful for state of the art applications like fast switching and optical clock distribution. The injection of free charges is a much faster physical effect, but the best reported results to date are limited in the 20 MHz range [8, 9], which is still to slow. Another improvement has been recently shown in a capacitive device [10], in which, recombination due to charge current flow is absent and hence the modulation frequency can reach the GHz range; on the other hand the very small effective area where the modulation is performed make its efficiency very small.

Concerning optoelectronics on Silicon the trend today, is for scaling waveguide dimensions into the micron and even submicron region, while until now dimensions are rather in the 5 to 10 μm range. Despite the inevitable difficulty in injecting light in submicron waveguides (also called photonics wires), the high index contrast of such structures will provide high field confinement and, consequently, the possibility to access extreme bending (μm radii). Very compact structures are one key element for optical clock distribution but to address such specific application very fast light modulation and light detectors are required.

Our invention, though concerning primarily the light modulation, is conceived also to be directly co-integrable in a system having Si-based photonics wires and SiGe photodetectors.
The device we propose is shown in figure 1. A Silicon photonic wire with dimensions in the range 10 x 10 to 200 x 200 nm^2 is wrapped in a thin (10 nm) oxide and again this last one is wrapped in a poly-silicon covering. This whole structure also behaves optically as a photonic wire, and it constitutes the typical GAA structure, which can be developed either as a transistor or as a capacitor. For thick Si wires the device will be composed of a doped Si which will be fully depleted at the threshold voltage thus enabling light modulation by charge variation. For thinner Si, it is possible to use light doped Si and to access the volume inversion region at the threshold voltage to create charge injection. In both cases electronic physics will not be related to charge recombination and, consequently, GHz modulation frequencies become accessible.
For optical reasons the total device structure should not exceed the single mode propagation condition, which has been roughly calculated to about "*Height x Width* < 0.15 μm^2". Special attention at the fabrication process needs also to be considered: the roughness of the Si surface must be kept well below ~10 nm rms in order to have reasonable propagation losses (< 1dB/cm); the poly-silicon also requires special process to keep low losses (< 10dB/cm). The effective modulation area being much larger than the one proposed in [10], the efficiency of this device can be much higher, thus keeping reasonable lengths (100 µm to 1 mm) which help keeping the device total losses low. Results reported in the literature concerning similar structures are very promising in terms of fabrication capability, but no publication exists yet on the device presented figure 1, with respect to its utilization as a light phase modulator.

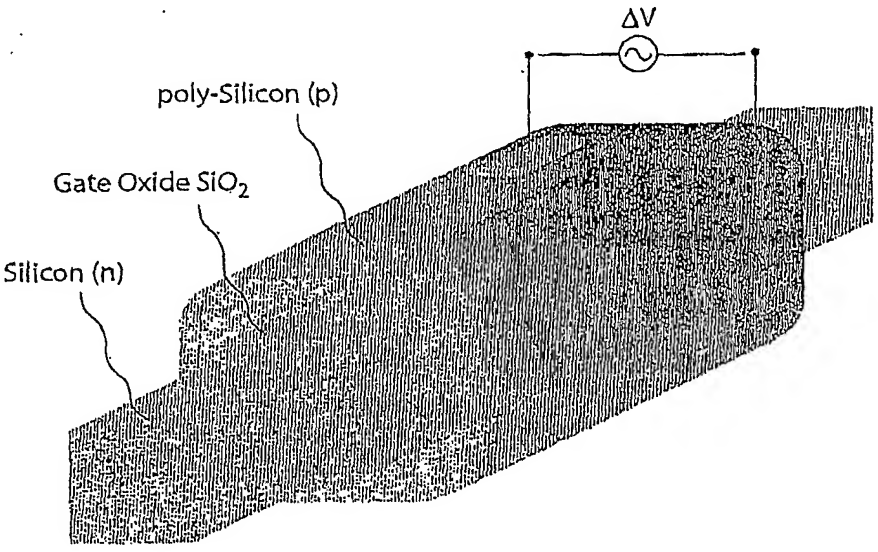

Figure 1. GAA-based Silicon light phase modulator.

We have performed preliminary simulations studies on the optical propagation properties and on the electronic properties of the presented device, and the results confirm our idea; more accurate studies are on going in order to optimize the device parameters and better predict its performances.
This device can be fabricated in a SON substrate by first selectively etching the SiGe buried layer in the region where the modulator will be realized, leaving a suspended Si wire which can be successively wrapped in oxide and poly-silicon. This process technique developed in ST microelectronics is a key technological requirement for the fabrication of this device.

Pillars, which provide material anchoring and electrical contact to the wire, can be made small enough to have negligible perturbation of the propagating light.
The use of SON substrates, as mentioned above, is an ideal choice also for co-integration of a Si/Ge photodetector, which is actually the most efficient way to fabricate a photodiode in a Silicon based technology for the IR spectral region.
In figure 2 it is schematically shown this principle: the Si/Ge sacrificial layer is not etched in correspondence of the area where a photodetector is required, the index difference between Silicon and Si/Ge is responsible for automatically coupling the light incoming from the suspended Si photonic wire into the photodetector active area.

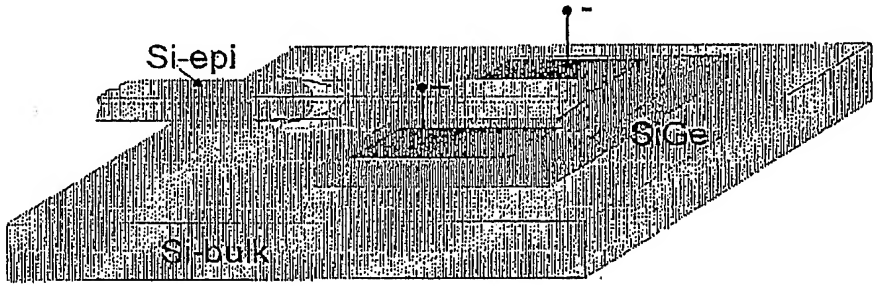

Figure 2. Schematic of co-integration of a Si/Ge photodiode with a Si photonic wire in SON substrates.

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Claim

1. Silicon light phase modulator based on the gate-all-around MOFSET technology.

Abstract

Silicon light phase modulator based on the gate-all-around MOFSET technology.